Physics 489 S 04 Lecture 25
Strongly interacting Electrons in solids
Kondo Effect; Mott Metal-Insulator Transitions; Hi-Tc materials
Aschroft and Mermin, Ch. 32, p 685-689 and Notes

1. Interactions between electrons lead to qualitative effects in solids
   Good, extensive review:
   M. Imada, A. Fujimori and Y. Tokura, Rev. Mod. Phys. 70, 1039-1263 (1998).

2. Kondo Effect
   Discovered experimentally - resistance minimum in metals
   Very hard to explain from any usual theory of scattering
   Happens with magnetic impurities
   Explanation:

   - P. W. Annderson, p. Nozieres, ... - breakdown of perturbation theory - bound state at Fermi surface of metal
   - K. G. Wilson, Rev. Mod. Phys. 75, 773 (1975) - Solution by renormalization group - Nobel Prize
   - Example of a new low energy scale introduced by electron-electron interactions

3. Metal-insulator transitions caused by interactions
   Recall that for non-interacting electrons in a perfect crystal, if there are an odd number of electrons per cell, the material MUST be a metal - examples: Na, Cu, ...
   What happens if there are localized states with strong interactions?

   - If interactions dominate - MUST be an insulator for an integer number of electrons per cell - whether the integer is even or odd
   - Hubbard model - simplest example
   - Mott metal-insulator transition as a function of the strength of the interaction - for strong interactions electrons localized to sites
   - Model applies to transition metal oxides
   - Example of La_2CuO_3 and other planar CuO materials - parent compounds of the Hi-Tc materials - magnetic insulators
   - Idealized as an example of a simple one-band square lattice

4. Metal-insulator transitions caused by doping
   Recall that for non-interacting electrons in a perfect crystal, if there are a non-integer number of electrons per cell, the material MUST be a metal - examples: metal alloys approximated as perfect crystals
   What happens if there strong interactions?

   - If the carriers can move there should be conduction even with large interactions!
   - Consider case with strong interactions but missing electrons (holes) - free to move! Example of doped La_2CuO_3 and other planar CuO materials - parent compounds of the Hi-Tc materials - two-dimensional metals
   - Are interactions the cause of Hi-Tc superconductivity - no one knows!